

Optimized Dose Distribution in Radiotherapy by JO-IMRT Technique for Head and Neck Cancer

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ABSTRACT: Purpose/Objectives: comparison of dose distribution results between 3D-CRT and MLC-IMRT techniques with JO-IMRT technique. Optimized implementation of JO-IMRT plans with irradiation field changes for 20 head and neck cancer patients.

Materials/Methods: use Prowess Panther 5.1 software to do the treatment planning for head and neck cancer patients by jaws only IMRT technique. Using direct aperture optimization (DAO), we have developed an inverse planning approach that is capable of producing efficient intensity modulated radiotherapy treatment plans than can be delivered without a multi-leaf collimator.

Results:

- In comparison to 3D-CRT, the JO-IMRT technique has generated better dose distribution in the target volume and reduced dose to healthy tissues.
- The results of dose distribution in the target volume of both MLC-IMRT and JO-IMRT techniques are the same.
- We recommend that the process of JO-IMRT plan with 7 irradiation fields has adopted to treat head and neck cancer patients.

KEYWORDS: intensity modulated radiation therapy (IMRT), Linear accelerator (LINAC), multi-leaf collimators (MLCs), Jaw only (JO).

I. INTRODUCTION

Intensity modulated radiation therapy is commonly delivered by modulating the radiation beam with multi-leaf collimator or compensator. Both methods produce a highly conformal dose distribution to the target volume. An alternative method for beam modulation is by using the standard collimator jaws. In this approach, the radiation beam is modulated by varying the dimensions of the collimator jaws. Prowess Inc. has developed a jaw-only IMRT (JO-IMRT) planning software based upon the Direct Aperture Optimization (DAO) method [1], [2], [3]. The purpose of this study is comparing the JO-IMRT plan to the 3D conformal radiation therapy (3D-CRT) [4], [5] and the MLCs-IMRT [6], [7],[8]. This work makes the use of simpler collimator consisting of only 4 collimator jaws.

II. METHOD AND MATERIALS

To study the efficacy of the JO-IMRT [9], we use commercially available planning system (Panther Prowess. Inc., CA) to create JO-IMRT plans and compare the result to some cases that we created with clinical planning system. This is a comparison of JO-IMRT to 3D-CRT and MLC based IMRT. Since the JO-IMRT is developed primarily for accelerators without multi-leaf collimator [10], these accelerator would most likely have a single low energy photon 6 MV, in the following cases, 6 MV photon was used for all JO-IMRT plans.

- JO-IMRT plan was performed for a plan with 7 fields divided to 7 segments and a plan with 1 field to supraclavicular nodes.

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- 3D-CRT plan was performed total 9 fields and 6 plans:
 - ✓ Plan 1 was created with 2 beam angles to meet the dose 40 Gy to PTV and cervical lymph nodes.
 - ✓ Plan 2 was created with 1 beam angle to meet the dose 40 Gy to low neck nodes.
 - ✓ Plan 3 was created with 2 beam angles to irradiate 20 Gy boost to tumor and neck nodes except spinal cord.
 - ✓ Plan 4 and plan 5 were created with 2 beam angles to irradiate 20 Gy boost to high neck nodes on the both sides.
 - ✓ Plan 6 was created with 2 beam angles to irradiate boost 6Gy to tumor for meeting the total dose of 66 Gy.

III.RESULTS

- 1) Comparison the results between JO-IMRT and 3D-CRT techniques
Patient Dinh Tien M who has cancer of nasopharyngeal was treated with 2 methods JO-IMRT and 3D-CRT. Fig.1 shows dose distribution of 2 plans: the solid lines represent results of the JO-IMRT plan while the broken lines represent the results of the 3D-CRT plan.

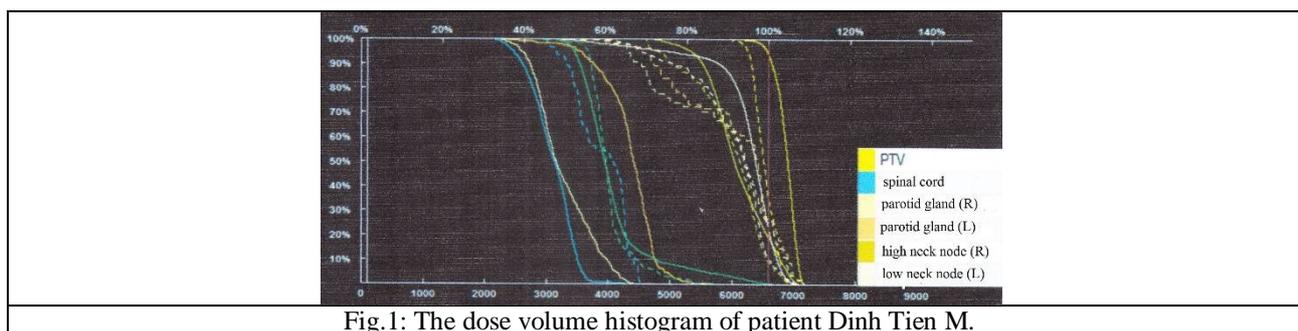


Fig.1: The dose volume histogram of patient Dinh Tien M.

From fig.1 we can see with JO-IMRT technique, 99.7% volume of PTV received 95% of prescribed dose while with 3D-CRT is only 94.6% of PTV's volume received such a dose. In 3D-CRT, parotid glands received very high dose in comparison to that of JO-IMRT.

Table 1 and table 2 are described dose distribution in both technique of patient Dinh Tien M.

Table1: The dose distribution to organs in JO-IMRT of patient Dinh Tien M.

Organs	Volume	DLV(%)	D-X(cGy)				V-X(%)			Min (cGy)	Max (cGy)	Mean (cGy)	Median (cGy)	Repeat (cGy)
	(cc)		50	30	1	110	100	95						
PTV	126.7	100.0	6910.0	6991.0	7150.0	0.0	93.9	99.7	5937.8	7231.2	6885.7	6909.5	6908.5	
Spinal cord	28.8	100.0	3136.0	3327.0	3736.0	0.0	0.0	0.0	2141.0	4508.3	3093.7	3135.5	2881.5	
Parotid gland (R)	14.0	100.0	3152.0	3525.0	4304.0	0.0	0.0	0.0	2256.4	4398.8	3264.7	3151.5	3207.5	
Parotid gland (L)	14.6	100.0	4409.0	4577.0	5286.0	0.0	0.0	0.0	2367.3	5622.6	4349.0	4408.5	4421.5	
High neck node (R)	120.5	100.0	6047.0	6376.0	7027.0	0.0	19.5	35.8	4639.9	7144.5	6101.2	6046.5	5954.5	
High neck node (L)	99.6	100.0	6387.0	6545.0	6953.0	0.0	22.7	64.5	2722.0	7122.6	6246.7	6386.5	6463.5	
Supraclavicular node	209.8	100.0	3943.0	4129.0	6403.0	0.0	0.3	1.8	3112.0	6786.2	4979.5	3942.5	3870.5	

Table 2: The dose distribution to organs in 3D-CRT of patient Dinh Tien M.

Organs	Volume	DLV(%)	D-X(cGy)				V-X(%)			Min (cGy)	Max (cGy)	Mean (cGy)	Median (cGy)	Repeat (cGy)
	(cc)		50	30	1	110	100	95						
PTV	126.7	100.0	6520.0	6637.0	6900.0	0.0	35.1	94.6	5998.1	6916.9	6531.5	6519.5	6373.5	
Spinal cord	28.8	100.0	4099.0	4258.0	4522.0	0.0	0.0	0.0	3007.2	4521.4	3904.9	4098.5	3413.5	
Parotid gland (R)	14.0	100.0	6207.0	6464.0	7128.0	0.0	25.9	44.4	4043.4	7127.7	5914.8	6197.5	4292.5	
Parotid gland (L)	14.6	100.0	6416.0	6518.0	7125.0	0.0	26.8	58.9	4614.2	7124.9	6080.8	6415.5	6438.5	
High neck node (R)	120.5	100.0	6139.0	6336.0	6921.0	0.0	9.6	39.3	3489.2	7124.4	5970.0	6138.5	6344.5	
High neck node (L)	99.6	100.0	6212.0	6397.0	6977.0	0.0	10.4	45.8	3774.0	7071.0	6013.7	6211.5	6558.5	
Supraclavicular node	209.8	100.0	3967.0	4053.0	5362.0	0.0	0.0	0.0	1740.5	5816.3	4021.7	3966.5	4052.5	

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- Median dose is 60 Gy to high neck nodes and 39.42 Gy to supraclavicular nodes. It meets requirement of the plan.
- Maximum dose or D_{max} to spinal cord is 45.08 Gy.
- Minimum dose or D_{min} to parotid glands is 32.64 Gy and 43.49 Gy that means one side exceed the allowed limit.

Evaluating the doses delivered by both techniques, we observed that:

- The dose delivered to parotid glands of JO-IMRT is good at one side and it is out of limit with 3D-CRT
- The dose delivered to spinal cord of 3D-CRT exceed the allowed limit while it is within limit of JO-IMRT.
- The dose delivered to PTV by JO-IMRT technique is very good while 3D-CRT is almost unsatisfactory.

2) *Comparison the results between JO-IMRT and MCL-IMRT techniques:*

Patient Nguyen Khac T. has cancer of nasopharyngeal (T3N2M0)

Prescribed dose of patient Nguyen Khac T. as follows:

Tumor: 70 Gy with 2Gy/fraction/day.

High neck nodes: 50 Gy.

Low neck nodes: 50 Gy.

Supraclavicular nodes: 50 Gy.

Spinal cord: < 45 Gy.

Fig.2 shows dose distribution of JO-IMRT and MLC-IMRT plans. The solid lines represent results of MLC-IMRT and the broken lines represent results of JO-IMRT of patient Nguyen Khac T.

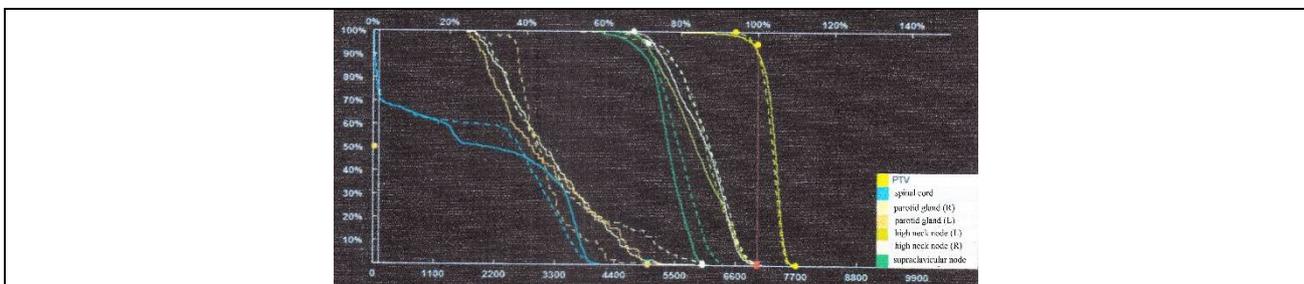


Fig.2: The dose distribution histogram of patient Nguyen Khac T.

Table 3: The dose distribution to organs in MLC-IMRT of patient Nguyen Khac T.

Organs	Volume (cc)	DLV(%)	D-X(cGy)					V-X(%)			Min (cGy)	Max (cGy)	Mean (cGy)	Median (cGy)	Repeat (cGy)
			50	30	1	110	100	95							
PTV	143.4	100.0	7317.0	7387.0	7601.0	0.1	91.1	98.2	5255.2	7738.9	7272.2	7316.5	7350.5		
Spinal cord	49.1	72.0	2143.0	3514.0	3953.0	0.0	0.0	0.0	17.8	4376.6	1967.4	2142.5	21.5		
Parotid gland (R)	8.2	100.0	3098.0	3720.0	5180.0	0.0	0.0	0.0	1768.5	5871.5	3223.4	3097.5	2070.5		
Parotid gland (L)	4.6	100.0	2909.0	3708.0	5008.0	0.0	0.0	0.0	1703.0	5258.4	3108.1	2905.5	4304.5		
High neck node (R)	66.2	100.0	5878.0	6272.0	6946.0	0.0	0.5	8.4	4290.3	7066.9	5880.3	5877.5	6406.5		
High neck node (L)	69.6	100.0	6096.0	6357.0	6874.0	0.0	0.5	5.9	4432.5	7136.4	5980.5	6095.5	6429.5		
Supraclavicular node	119.2	100.0	5380.0	5560.0	5988.0	0.0	0.0	0.0	3681.6	6315.3	5363.0	5379.5	5389.5		

Table 4: The dose distribution to organs in JO-IMRT of patient Nguyen Khac T.

Organs	Volume (cc)	DLV(%)	D-X(cGy)					V-X(%)			Min (cGy)	Max (cGy)	Mean (cGy)	Median (cGy)	Repeat (cGy)
			50	30	1	110	100	95							
PTV	143.4	100.0	7268.0	7349.0	7560.0	0.0	90.4	99.5	6081.1	7690.2	7243.5	7267.5	7267.5		
Spinal cord	49.1	76.5	2658.0	3140.0	3963.0	0.0	0.0	0.0	13.3	4265.4	1972.9	2657.5	15.5		
Parotid gland (R)	8.2	100.0	3095.0	3589.0	6038.0	0.0	0.0	0.0	1723.2	6080.4	3321.6	3094.5	2420.5		
Parotid gland (L)	4.6	100.0	3033.0	3314.0	4424.0	0.0	0.0	0.0	2224.5	4961.5	3121.2	2982.5	2652.5		
High neck node (R)	66.2	100.0	6056.0	6303.0	6965.0	0.0	0.7	7.8	3512.2	7156.5	6000.3	6054.5	5867.5		
High neck node (L)	69.6	100.0	6137.0	6394.0	6982.0	0.0	0.8	9.9	3141.1	7172.9	6063.7	6136.5	5663.5		
Supraclavicular node	119.2	100.0	5565.0	5799.0	6319.0	0.0	0.0	0.0	4174.4	6390.1	5565.5	5564.5	5759.5		

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From fig.2, table 3 and table 4, we can evaluate in detail both MLC-IMRT and JO-IMRT plans of patient Nguyen Khac T. with nasopharyngeal cancer as follows:

Both methods result in good dose distribution to tumor, cervical lymph nodes and supraclavicular nodes. The maximum doses delivered to spinal cord are 43.7 Gy and 42.6 Gy. That means they are under the limit. The minimum doses delivered to parotid glands are 32 Gy, 32 Gy and 33 Gy. The values are within the limit of parotid gland [11], [12]. The JO-IMRT and MLC-IMRT plans give a uniform dose distribution.

Fig.3 and fig.4 show the dose distribution of 3D and 2D from JO-IMRT and MLC-IMRT

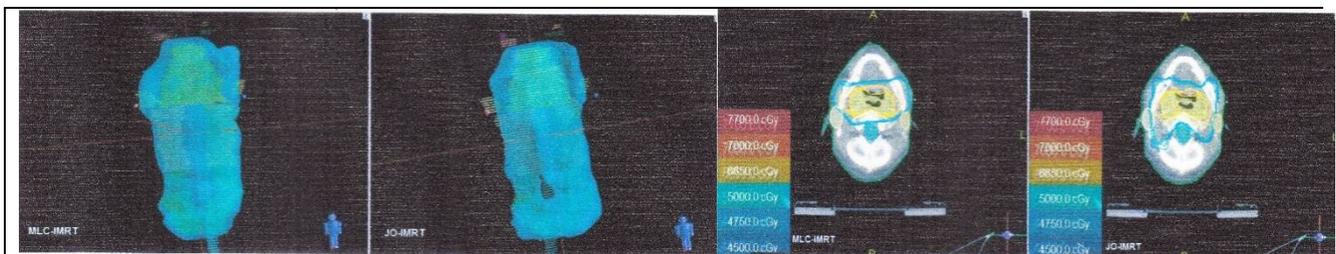


Fig.3: The dose distribution from 3D images of MLC-IMRT and JO-IMRT plans (patient Nguyen Khac T)

Fig.4: The dose distribution from 2D images of MLC-IMRT and JO-IMRT plans (patient Nguyen Khac T.)

From distribution of 2D images, we observed that JO-IMRT plan protected spinal cord very well and the low dose distribution was wider than that of MLC-IMRT. Although the dose distribution of 2 plans was similar, the optimization process with jaw was more difficult to do than MLC process and it required the planners to be very flexible.

3) Optimizing the dose distribution of JO-IMRT plan:

We figured out a plan with 7 fields that reached all criteria of a perfect plan (see table 5).

Table 5: Statistical results of the dose distribution from head and neck cancer treatment plans by the JO-IMRT:

Structure	Prescribed dose	5 fields	6 fields	7 fields	8 fields	9 fields
PTV: min dose	≥ 57Gy	57÷60	55÷60	60÷64	60÷64	60÷63
PTV: max dose	≤ 77Gy	76÷79	74÷78	75÷77	74÷77	75÷77
100% PTV	≥ 95%	94 ÷97	92 ÷98	95÷100	95÷100	95÷100
High neck nodes: Mean dose	≥50Gy	50÷60	50÷60	50÷60	50÷60	50÷60
Supraclavicular nodes: mean dose	≥ 40Gy	40÷50	40÷50	40÷50	40÷50	40÷50
Parotid glands: mean dose	≤ 42Gy	36÷37	40÷60	30÷35	30÷39	30÷33
Spinal cord: max dose	≤ 45Gy	44÷45	44÷ 49	40÷43	40÷46	40÷44

The bold values in the table are not satisfactory to the plan.

7 fields is the result of this work and it is recommended for head and neck cancer treatment process by the JO-IMRT technique.

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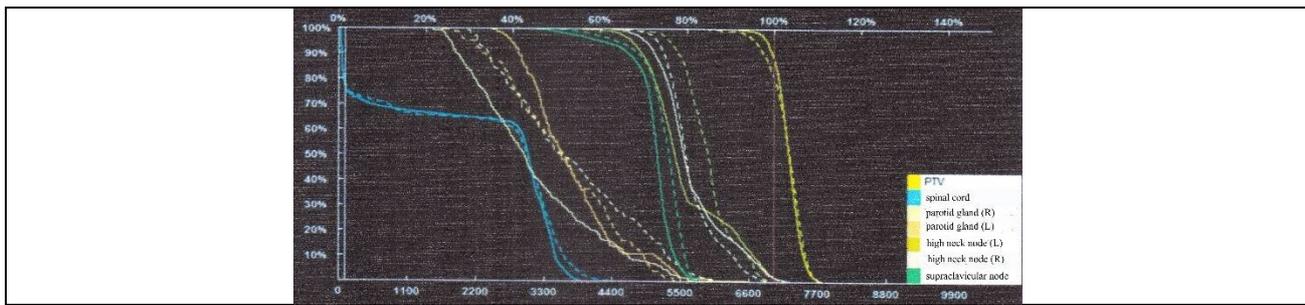


Fig.5: DVH curves of the 7 field plan (solid lines) and the 5 field plan (broken lines) of patient Pham Minh K.

In the histogram, we can see clearly that the low dose region of PTV from the 7 field plan is significantly higher than that from 5 field plan.

Table 6: The dose distribution to organs from 7 field JO-IMRT plan of patient Pham Minh K.

Organs	Volume	DLV(%)	D-X(cGy)			V-X(%)			Min	Max	Mean	Median	Repeat
	(cc)	(%)	50	30	1	110	100	95	(cGy)	(cGy)	(cGy)	(cGy)	(cGy)
PTV	142.4	100.0	7269.0	7348.0	7550.0	0.0	93.9	100.	6682.8	7706.8	7255.9	7268.5	7213.5
Spinal cord	48.4	80.4	2496.0	2923.0	3812.0	0.0	0.0	0.0	36.9	4267.4	2005.7	2495.5	40.5
Parotid gland (R)	8.2	100.0	3996.0	4504.0	6170.0	0.0	0.0	0.0	1664.5	6484.3	3952.4	3995.5	2220.5
Parotid gland (L)	4.7	100.0	4013.0	4659.0	6200.0	0.0	0.0	0.6	2892.1	6675.9	4160.7	4012.5	3329.5
High neck node (R)	66.3	100.0	5890.0	6093.0	7235.0	0.0	3.2	7.6	4367.6	7346.0	5913.9	5889.5	5837.5
High neck node (L)	69.6	100.0	5878.0	6119.0	7057.0	0.0	2.0	8.0	3626.9	7176.7	5915.7	5877.5	5746.5
Supraclavicular node	119.8	100.0	5243.0	5397.0	6056.0	0.0	0.0	0.0	3280.7	6155.6	5223.2	5242.5	5322.5

Table 6 shows with 7 field JO-IMRT plan, there is 93.9% volume of tumor received 100% prescribed dose while it is only 81% with the 5 field plan.

100% PTV volume of the 7 field plan received 95% prescribed dose.

The maximum dose delivered to spinal cord is 42.6 Gy with the 7 field plan and 44.3 Gy with the 5 field plan. The dose delivered to nodes and parotid glands is equivalent.

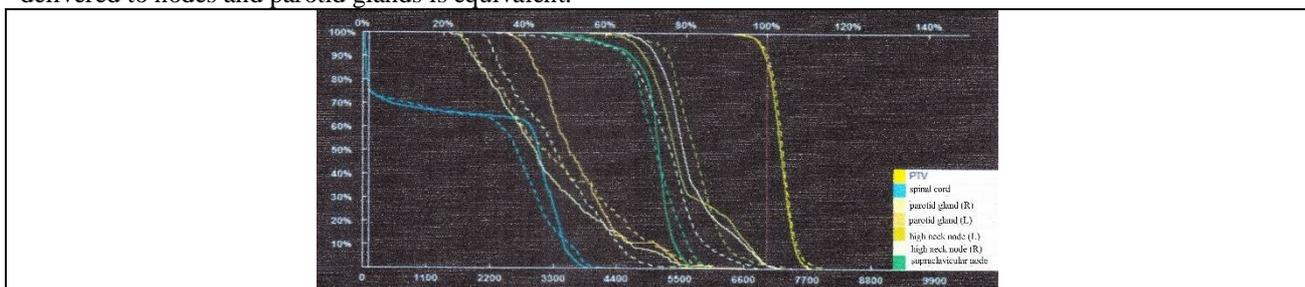


Fig.6: DVH curves of the 7 field plan (solid lines) and the 9 field plan (broken lines) of patient Pham Minh K.

Table 7: The dose distribution to organs from 9 field JO-IMRT plan of patient Pham Minh K.

Organs	Volume	DLV(%)	D-X(cGy)			V-X(%)			Min	Max	Mean	Median	Repeat
	(cc)	(%)	50	30	1	110	100	95	(cGy)	(cGy)	(cGy)	(cGy)	(cGy)
PTV	142.4	100.0	7274.0	7372.0	7860.0	2.8	91.2	99.3	6302.3	8123.4	7273.2	7273.5	7243.5
Spinal cord	48.4	77.2	2664.0	3030.0	3935.0	0.0	0.0	0.0	29.1	4453.6	2060.6	2663.5	37.5
Parotid gland (R)	8.2	100.0	3332.0	3831.0	5019.0	0.0	0.0	0.0	1997.9	5628.0	3352.3	3331.5	4036.5
Parotid gland (L)	4.7	100.0	3164.0	4100.0	6151.0	0.0	0.0	0.0	1695.6	6416.8	3383.7	3163.5	2049.5
High neck node (R)	66.3	100.0	5755.0	5966.0	7243.0	0.0	1.5	4.3	3846.6	7446.1	5768.3	5754.5	5781.5
High neck node (L)	69.6	100.0	5332.0	5552.0	6749.0	0.0	0.0	1.9	1855.7	6882.8	5251.8	5331.5	5474.5
Supraclavicular node	119.8	100.0	5079.0	5317.0	5926.0	0.0	0.0	0.0	3132.9	6085.8	5067.6	5078.5	4874.5

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The values of the dose from table 7 show that there is 2.8% PTV volume received the dose that higher than 110% the prescribed dose, it exceeds safe value.

IV. CONCLUSION

From a radiobiological point view, the JO-IMRT appears to be an effective strategy for the treatment of head and neck cancers.

Our results prove that the 7 field JO-IMRT plan has adopted to treat head and neck cancer patients.

REFERENCES

- [1].Matt A Earl, David M. Shepard, Xingsheng Yu, Method for the planning and delivery of radiation therapy, United States Patent, 2008
- [2].D. M Shepard, M.A. Earl, X.A. Li, S. Naqvi, C. Yu, "Direct Aperture Optimization: A turnkey solution for step and shoot IMRT", Med. Phys 29(6), pages 1007-1018, June 2002
- [3].Chunhua Men, H. Edwin Romeijn, Z. Caner Taskin, James F. Dempsey, An exact approach to direct aperture optimization in IMRT treatment planning, Phys. Med. Biol, 52(2007), 7333-7352
- [4].Faiz M. Khan, The Physics of Radiation Therapy 3rd Edition, Lippincott Williams & Wilkins, New York, 2003
- [5].Faiz M. Khan, Treatment Planning in Radiation Oncology, 2nd Edition, Lippincott Williams & Wilkins, New York, 2007
- [6].Matja Jeraj, Vlado Roba, "Multileaf collimator in radiotherapy", Radiol Oncol 2004, 38(3), pages 235-240
- [7].Jame M. Galvin, the multileaf collimator a complete guide, Jefferson Medical School,
The web available: <https://www.aapm.org/meetings/99AM/pdf/2787-9625.pdf>
- [8].Jefferey V. Siebers, Mar Lauterbach, Paul J. Keall, Radhe Mohan, "Incorporating multi-leaf sequencing into iterative IMRT optimixation", Med. Phys 29(6), pages 952-959, June 2002
- [9].John Nguyen, Method for intensity modulated radiation treatment using independent collimator jaws, United States Patent, 2007
- [10].The web available: https://euromechanics.com/mlc/custom-mlc.html?gclid=EAlaIQobChMIgemE1-Og2QIVhI-PCh0W7QOiEAAYASAAEgKm8vD_BwE
- [11].The American Association of Physicists in Medicine, Task Group No.35 Medical accelerator safety considerations, American Institute of Physics, 1996
- [12].The American Association of Physicists in Medicine, Task Group No.119 IMRT commissioning tests instructions for planning, measurement and analysis, American Institute of Physics, 2009